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EXCITATION LIGHT SOURCE DEVICE

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Abstract

PROBLEM TO BE SOLVED: To provide an excitation light source device which enables to multiplex the excitation light of many wavelengths and output with high power.

SOLUTION: This excitation light source device consists of excitation light sources 1 each of which outputs an excitation light of a different wavelength from the others, and a wavelength multiplexer 2 each of which multiplexes a light of a different wavelength from the others. Each excitation light source 1 is provided with a laser diode 101a through 108b, and an excitation light output fiber 8 which forms a gratings 22 reflecting light of a different wave length from each other. To four light input parts 201, 202, 207 and 208 of the wavelength multiplexer 2, light output parts of a polarized synthesizer 3 which multiplexes two polarized wave lights with different polarized wave states from each other are connected, respectively. To the light output part of each polarized wave synthesizer 3, the two excitation light sources 1 which output polarized light with different polarized wave state and different wave length from the other are connected, respectively. The excitation light sources 1 are connected to light input parts 203, 204, 205 and 206.

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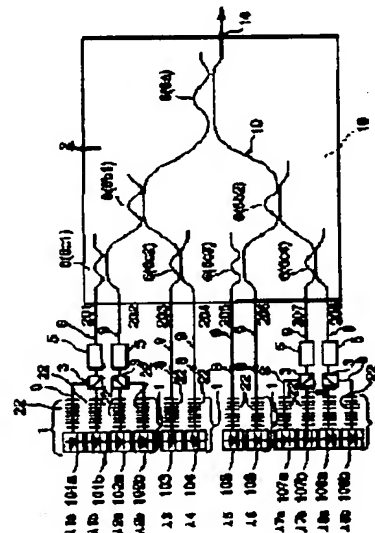
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(54) 発明の名称 励起光源装置

(57) (要約)

【課題】 多数の波長の励起光を合波して高出力で出力できる励起光源装置を提供する。

【解決手段】 互いに異なる波長の励起光を出力する複数の励起光源1と、互いに異なる複数の波長の光を合波する波長合波器2を設けて励起光源装置を形成する。各励起光源1はレーザダイオード101a~101bと、互いに異なる波長の光を反射するグレーティング22を形成した励起光出力ファイバ8により構成する。波長合波器2の4つの光入力部201、202、207、208にそれぞれ、互いに偏波状態が異なる2つの偏波光を合波する偏波合成器3の光出力部を接続し、各偏波合成器3の光入力部にはそれぞれ、互いに偏波状態と波長が異なる偏波光を出力する2つの励起光源1をそれぞれ接続する。光入力部203、204、205、206に励起光源1を接続する。



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【特許請求の範囲】

【請求項1】 互いに異なる複数の波長の光を合波する波長合波器を有し、該波長合波器の1つ以上の光入力部に、互いに偏波状態が異なる2つの偏波光を合波する偏波合波器の光出力部が接続され、該偏波合波器の光入力部には互いに偏波状態と波長が異なる偏波光を出力する2つの励起光源がそれぞれ接続されていることを特徴とする励起光源装置。

【請求項2】 波長合波器は2本の入射側伝送路からそれぞれ入射される波長の異なる光を合波して1本の出射側伝送路に伝送する第1段の光合波手段を複数有し、これら第1段の1対ずつの光合波手段の光出力をさらに光合波する第2段の光合波手段を接続して両段の対の光合波手段の光出力を後段の光合波手段に接続して形成されていることを特徴とする請求項1記載の励起光源装置。

【請求項3】 それぞれの光合波手段により合波する合波光中心波長はそれぞれ固有の周期を有しており、 $(n-1)$ 段目(n は2以上の整数)に設けられた光合波手段の固有の周期は n 段目に設けられた光合波手段の固有の周期の整数倍と成していることを特徴とする請求項2記載の励起光源装置。

【請求項4】 光合波手段はそれぞれ2つの方向性結合器を備えたマッハツェンダ干渉型合波手段としたことを特徴とする請求項2又は請求項3記載の励起光源装置。

【請求項5】 方向性結合器は溶融型ファイバコブラとしたことを特徴とする請求項4記載の励起光源装置。

【請求項6】 マッハツェンダ干渉型合波手段は光導波回路により形成したことを特徴とする請求項4記載の励起光源装置。

【請求項7】 光合波手段は溶融型ファイバコブラとしたことを特徴とする請求項2又は請求項3記載の励起光源装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、光通信用の光増幅器に適用される励起光源装置に関するものであり、特に波長分割多重伝送システムや伝送距離の長い光海底伝送システム等で用いられる光増幅装置用の励起光源装置に関するものである。

【0002】

【従来の技術】近年、波長分割多重伝送システムが盛んに検討されている。波長分割多重伝送システムは、光伝送路としての1本の光ファイバに異なる波長の光信号を複数多重して伝送するシステムであり、伝送容量を波長多重分だけ拡大できるように分光を浴びている。

【0003】波長分割多重伝送システムにおいて、光伝送路の途中には光増幅器が設けられ、この光増幅器によって伝送光(光信号)を増幅しながら伝送させることが行なわれている。光増幅器としては、光信号を光のまま

増幅させることができる光ファイバ型の光増幅器の適用が有効であり、現在、エルビウムドープ光ファイバを用いたエルビウムドープ光ファイバ型光増幅器(EDFA)が一般的に用いられている。

【0004】ところで、上記波長分割多重伝送システムにおいて、波長多重度を増やし、伝送容量を増大せよとする試みがなされており、波長多重度を増やす1つの方法として波長帯域を広げることが考えられている。

【0005】しかしながら、波長多重伝送システム用として用いられている上記EDFAは、一般に、最大30nmの利得帯域しか持たず、たとえエルビウムドープ光ファイバの長さを長くしてEDFAの利得帯域を長波長側に広げたとしても、EDFAの利得帯域は最大60nm程度である。しかも、EDFAの利得は波長依存性を有しており、利得帯域における利得平坦性がよくないために、EDFAを波長多重伝送システムに適用する場合は、EDFAの利得平坦化を行なう利得平坦化装置を必要とするといった問題もあった。

【0006】そこで、最近では、EDFAに代わる光増幅器として、非線形性が高い光ファイバを用いたRaman増幅型光増幅器が注目されてきた。このRaman増幅型光増幅器は、非線形性が高い光ファイバに強い励起光を入力したときに生じるRaman効果を利用したものである。

【0007】利得平坦性が良好なRaman増幅を実現するためには、1THz程度の狭い周波数間隔の互いに波長が異なる複数の励起光を多重化することが求められ、この多重化した励起光を非線形性が高い光ファイバに入力することにより、利得平坦化装置を用いなくても100nm以上の広い帯域で高い利得を有するRaman増幅型光増幅器の実現を図ることができる。

【0008】Raman増幅を利用した装置の例として、例えば公知文献「Y.Emori et al., OFC'99 PD-19」には、波長間隔7.5nmと波長間隔15nmを繰り返して波長1405nm~1510nmの範囲で互いに異なる12の波長の光を多重化する例が報告されている。

【0009】上記波長多重化のために用いられる励起光源装置の構成は、図13に示されるものであり、上記12波長(同図において、 $\lambda_1, \lambda_2, \dots, \lambda_{12}$)の光をそれぞれ出力する励起光源1と、それぞれの励起光源1から出力された上記波長の光を合波する波長合波器2とにより構成されている。

【0010】波長合波器2は、例えば図14に示すようなマッハツェンダ干渉型合波手段6を複数有している。マッハツェンダ干渉型合波手段6は、同図に示すように、2本のアーム(光路)35により形成されており、2本の入射側伝送路5a、5bからそれぞれ入射される波長の異なる光(同図では λ_a, λ_b)を合波して1本の出射側伝送路5cに伝送するものである。なお、図13に示した波長合波器2は光導波回路により形成されて

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おり、この場合、上記アーム35は光導波回路のコアにより形成される。

【0011】図14に示すように、マッハツェンダ干渉型合波手段6の入射側伝送路5a、5bと出射側伝送路5cとの間には、2つの方向性結合器12と、これらの方向性結合器12に挟まれた光路長差部13とが形成され、この光路長差部13において、2本のアーム35の長さが互いに異なる。光路長差部13におけるアーム35の長さの差によって、マッハツェンダ干渉型合波手段6により合波する光の波長間隔が決定される。

【0012】図13に示すように、前記波長合波器2は、光の入射側に上記構成の第1段のマッハツェンダ干渉型合波手段6を複数有し（図13では6個並設し）、これら第1段の1対ずつのマッハツェンダ干渉型合波手段6の光出力をさらに光合波する第2段のマッハツェンダ干渉型合波手段6を接続して、前段の対のマッハツェンダ干渉型合波手段6の光出力を後段のマッハツェンダ干渉型合波手段6でさらに光合波するという如く、合計11個のマッハツェンダ干渉型合波手段6を4段に接続して形成されている。

【0013】本発明が解決しようとする課題】ところで、上記のような波長合波器2を構成するマッハツェンダ干渉型合波手段6において、方向性結合器12の設計には留意が必要である。それというのは、方向性結合器12の結合効率には波長依存性を有しているために、マッハツェンダ干渉型合波手段6の出力部32と交差する側の光入力部（クロスポート）30に入力する波長の、方向性結合器12による結合効率を50%近傍にしなければ損失が大きくなってしまふのである。なお、このことは登録特許第2557966号に記載されている。

【0014】しかしながら、図13に示したような屈折率変調型の波長合波器2においては、波長合波器2を形成するマッハツェンダ干渉型合波手段6の個数が11個、段数が4段あり、1つのマッハツェンダ干渉型合波手段6で合波する波長が複雑となって上記結合効率を50%近傍にするような設計が困難である。

【0015】また、上記屈折率変調型に適用されている波長合波器2は、マッハツェンダ干渉型合波手段6の接続段数も多い。マッハツェンダ干渉型合波手段6の段数が多くなるにつれて波長合波器2により合波する各波長の帯域幅が狭くなるため、マッハツェンダ干渉型合波器6の接続段数が多い波長合波器2においては、各屈折率光のスペクトル幅（バンド幅）の一部ずつしか波長合波器2を通過できなくなり、それに伴い、波長合波器2の挿入損失が大きくなるために、合波屈折率光の強度が低減してしまう。

【0016】したがって、この波長合波器2を用いた上記従来のRaman増幅型光増幅器は、Raman増幅効率を向上させることができなかった。

【0017】本発明は上記課題を解決するために成されたものであり、その目的は、Raman増幅型光増幅器のRaman増幅効率の向上を図れるように、多数の波長の屈折率光を合波して高出力で出力できる屈折率増幅器を提供することにある。

【0018】

【課題を解決するための手段】上記目的を達成するために、本発明は次のような構成をもって課題を解決するための手段としている。すなわち、第1の発明は、互いに異なる複数の波長の光を合波する波長合波器を有し、該波長合波器の1つ以上の光入力部に、互いに偏波状態が異なる2つの偏波光を合波する偏波合成器の光出力部が接続され、該偏波合成器の光入力部には互いに偏波状態と波長が異なる偏波光を出力する2つの屈折率増幅器がそれぞれ接続されている構成をもって課題を解決する手段としている。

【0019】また、第2の発明は、上記第1の発明の構成に加え、前記波長合波器は2本の入射側伝送路からそれぞれ入射される波長の異なる光を合波して1本の出射側伝送路に伝送する第1段の光合波手段を複数有し、これら第1段の1対ずつの光合波手段の光出力をさらに光合波する第2段の光合波手段を接続して前段の対の光合波手段の光出力を後段の光合波手段でさらに光合波するという如く、光合波手段を複数段に接続して形成されている構成をもって課題を解決する手段としている。

【0020】さらに、第3の発明は、上記第2の発明の構成に加え、前記それぞれの光合波手段により合波する合波光中心波長はそれぞれ固有の周期を有しており、 $(n-1)$ 段目（ n は2以上の整数）に設けられた光合波手段の固有の周期は n 段目に設けられた光合波手段の固有の周期の整数倍と成している構成をもって課題を解決する手段としている。

【0021】さらに、第4の発明は、上記第2又は第3の発明の構成に加え、前記光合波手段はそれぞれ2つの方向性結合器を備えたマッハツェンダ干渉型合波手段とした構成をもって課題を解決する手段としている。

【0022】さらに、第5の発明は、上記第4の発明の構成に加え、前記方向性結合器は溶融型ファイバコブラとした構成をもって課題を解決する手段としている。

【0023】さらに、第6の発明は、上記第4の発明の構成に加え、前記マッハツェンダ干渉型合波手段は光導波回路により形成した構成をもって課題を解決する手段としている。

【0024】さらに、第7の発明は、上記第2又は第3の発明の構成に加え、前記光合波手段は溶融型ファイバコブラとした構成をもって課題を解決する手段としている。

【0025】上記構成の本発明において、互いに異なる複数の波長の光を合波する波長合波器の1つ以上の光入力部には、互いに偏波状態が異なる2つの偏波光を合波

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する偏波合成器が接続され、該偏波合成器には互いに偏波状態と波長が異なる偏波光を出力する2つの励起光源が接続されているので、2つの励起光源からそれぞれ出力する偏波光が偏波合成器で台波されて波長合波器に入力される。

【0026】図13に示したような従来の励起光源装置の構成においては、波長合波器に設ける光入力部の個数は、波長合波器によって合波する波長数（同図では12個）必要であったが、本発明においては、互いに偏波状態と波長が異なる偏波光を偏波合成器により台波し、その合波光を波長合波器の1つ以上の光入力部から波長合波器に入力するので、例えば図1に示すように、励起光源装置の数が同じ場合に、波長合波器に設ける光入力部の個数を偏波合成器の配置数分だけ少なくすることが可能となる。

【0027】特に、波長合波器は、例えばマッハツェンダ干渉型合波手段等の光合波手段を複数段接続して形成しているものが一般的に用いられており、この種の波長合波器において光入力部の個数が増えると、それに伴う光合波手段の個数や段数を多くせざるを得ず、それに伴う波長合波器の挿入損失の増加が問題であったが、本発明においては、波長合波器に設ける光入力部の個数を偏波合成器の配置数分だけ少なくすることができ、波長合波器を形成する光合波手段の個数や段数を低減することができ、段数の多い波長合波器において問題であった合波光の波長帯域幅狭化の問題を低減でき、波長合波器の挿入損失を格段に低減可能となる。

【0028】したがって、本発明は、多数の波長の励起光を合波して高出力で出力できる励起光源装置を提供することが可能となり、それにより、Raman増幅型光増幅器のRaman増幅効率の向上を図ることが可能となる。

【0029】

【発明の実施の形態】以下、本発明の実施の形態を図面に基いて説明する。なお、本実施形態の説明において、従来例と同一名称部分には同一符号を付し、その重複説明は省略する。図1には、本発明に係る励起光源装置の第1実施形態例が示されている。

【0030】同図に示すように、本実施形態例の励起光源装置は、互いに異なる波長（ $\lambda_1, \lambda_2, \dots, \lambda_n$ ）の励起光を出力する複数の（同図では12個）の励起光源1と、互いに異なる複数の波長の光を台波する波長合波器2を有している。各励起光源1はレーザダイオード101a、102b、 \dots 108bと励起光出力ファイバ8とを有しており、各励起光出力ファイバ8にはそれぞれ互いに異なる上記波長の光を反射するグレーティング（ファイバグレーティング）22が形成されている。

【0031】波長合波器2の1つ以上（同図では4つ）の光入力部（入力ポート）201、202、207、2

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08には、それぞれ、光入力ファイバ9とデモラライザ5を介して、互いに偏波状態が異なる2つの偏波光を台波する偏波合成器3の光出力部が接続されている。これらの偏波合成器3の光入力部にはそれぞれ、互いに偏波状態と波長が異なる偏波光を出力する2つの励起光源1の光出力部がそれぞれ接続されている。

【0032】それぞれの偏波合成器3に接続されている2つの励起光源1は、その一方が直線偏波を出力し、他方が水平偏波を出力するように構成されている。また、偏波合成器3は、それぞれ対応する2つの励起光源1から出力される波長の光を含む帯域の偏波を低損失で台波する機能を有しているために、偏波合成器3による上記水平偏波と垂直偏波の合成は、非常に低損失で行われるものである。

【0033】さらに、本実施形態例においては、偏波合成器3の出力側にデモラライザ5を設けることにより、偏波合成器3で偏波合成した上記直線偏波と水平偏波の励起光の偏波状態を無偏波状態として、波長合波器2の偏波依存性損失が波長合波器2による合波光に与える影響を抑制している。

【0034】前記波長合波器2の残りの光入力部（入力ポート）203、204、205、206には、光入力ファイバ9を介して、それぞれ、1つずつ励起光源1が接続されている。なお、本実施形態例は、光入力部203、204、205、206に接続されている励起光源1からの光も無偏波状態にしている。

【0035】各励起光源1に形成されている前記グレーティング22の反射光波長は、互いに異なる $\lambda_1, \lambda_2, \dots, \lambda_n$ までの12種類の波長であり、各グレーティング22は対応するレーザダイオード101a、102b、 \dots 108bの外部共振器として機能するものである。このように、グレーティング22を外部共振器として機能させることにより、それぞれのグレーティング22の反射光波長（ $\lambda_1, \lambda_2, \dots, \lambda_n$ ）をそれぞれの励起光源1から狭い発振スペクトル幅で出力可能とし、かつ、各励起光源1の出力を安定的なものとしている。

【0036】前記波長合波器2は、図2に示すように、火炎増幅法（例えばN.Takato et al., J.Lichtwave Techn., vol.16, pp.1003-1010, 1998参照のこと）を用いて、シリコン基板19上に下部クラッド層18とコア回路10を順に形成し、さらに上部クラッド層17でコア回路10を埋め込んだ光導波回路により形成されている。なお、火炎増幅法による光導波回路の形成方法の詳細説明は省略する。

【0037】コア回路10は、図1に示すように、波長合波器2を形成する光合波手段としてのマッハツェンダ干渉型合波手段6を複数有し、光入力部201～208側に第1段のマッハツェンダ干渉型合波手段6（6c1～6c4）を複数（4個）並列している。

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低損失で合波され、出力されることになる。

【0053】また、マッハツェンダ干渉型合波手段6bの兩段にさらにマッハツェンダ干渉型合波手段6を接続する場合は、上記と同様に、マッハツェンダ干渉型合波手段6の固有の周期を決定し、それに対応させて光路長差を決定していく。

【0054】このように、波長合波器2の設計に際し、波長合波器2を構成するマッハツェンダ干渉型合波手段6のうち、光出力部14側のマッハツェンダ干渉型合波手段6によって、波長合波器2に接続する全ての励起光源1からの出力光を合波できるように、マッハツェンダ干渉型合波手段6により合波する合波光中心波長の固有の周期（周波数間隔 Δf ）を決定し、この周期に対応させてマッハツェンダ干渉型合波手段6の光路長差 ΔL を決定し、このマッハツェンダ干渉型合波手段6の兩段に接続するマッハツェンダ干渉型合波手段6については、上記のようにして順次、固有の周期と光路長差を決定していく。

【0055】そうすると、波長合波器2に接続する全ての励起光源1からの出力光を低損失で合波できる波長合波器2が形成される。

【0056】本実施形態例では、上記のようにして、波長合波器2を形成するそれぞれのマッハツェンダ干渉型合波手段6により合波する合波光中心波長を決定し、例えば図1の光入力部201から入力された光がマッハツェンダ干渉型合波手段6c1、6b1、6aを順に通って光出力部14から出力されるとききの光透過特性は、図3の(a)に示す特性となるようにした。この特性から明らかなように、光入力部201から、波長 λ_1 、 λ_2 の光を入力した場合、これらの波長の光が波長合波器2によって低損失で合波されて光出力部14から出力される。

【0057】同様に、光入力部202から入力された光がマッハツェンダ干渉型合波手段6c1、6b1、6aを順に通って光出力部14から出力されるとききの光透過特性は、同図の(b)に示すものとなり、本実施形態例では、光入力部202から、波長 λ_1 、 λ_2 の光を入力した場合に、これらの波長の光が波長合波器2によ

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って低損失で合波されて光出力部14から出力される。

【0058】また、同様に、同図の(c)、(d)には、それぞれ、光入力部203から入力された光と光入力部204から入力された光が、マッハツェンダ干渉型合波手段6c2、6b1、6aを順に通って光出力部14から出力されるとききの光透過特性が示されている。本実施形態例では、光入力部203から波長 λ_1 の光を入力し、光入力部204から波長 λ_2 の光を入力した場合に、これらの波長の光が波長合波器2によって低損失で合波されて光出力部14から出力される。

【0059】さらに、図4の(a)、(b)には、それぞれ、光入力部205から入力された光と光入力部206から入力された光が、マッハツェンダ干渉型合波手段6c3、6b2、6aを順に通って光出力部14から出力されるとききの光透過特性が示されている。本実施形態例では、光入力部205から波長 λ_1 の光を入力し、光入力部206から波長 λ_2 の光を入力した場合に、これらの波長の光が波長合波器2によって低損失で合波されて光出力部14から出力される。

【0060】さらに、同図の(c)には、光入力部207から入力された光がマッハツェンダ干渉型合波手段6c4、6b2、6aを順に通って光出力部14から出力されるとききの光透過特性が示されており、本実施形態例では、光入力部207から、波長 λ_1 、 λ_2 の光を入力した場合に、これらの波長の光が波長合波器2によって低損失で合波されて光出力部14から出力される。

【0061】さらに、同図の(d)には、光入力部208から入力された光がマッハツェンダ干渉型合波手段6c4、6b2、6aを順に通って光出力部14から出力されるとききの光透過特性が示されており、本実施形態例では、光入力部208から、波長 λ_1 、 λ_2 の光を入力した場合に、これらの波長の光が波長合波器2によって低損失で合波されて光出力部14から出力される。

【0062】なお、各波長 λ_1 、 λ_2 、 \dots の具体的な値は、表1に示す値である。

【0063】

【表1】

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波長(μm)	入力ポート	波長番号
1411	207	λ_{7a}
1418	206	λ_{2a}
1424	205	λ_5
1431	204	λ_4
1438	208	λ_{5a}
1445	201	λ_{1a}
1452	206	λ_6
1459	203	λ_3
1466	207	λ_{7a}
1474	202	λ_{2a}
1486	208	λ_{5a}
1487	201	λ_{1a}

【0064】本実施形態例は以上のように構成されており、励起光源1から出力される波長 λ_{1a} 、 λ_{2a} の光が偏波合成器3により合波されて波長合波器2の光入力部201に入力され、同様に、波長 λ_{3a} 、 λ_{4a} の光が偏波合成器3により合波されて波長合波器2の光入力部202に入力され、波長 λ_{5a} 、 λ_{6a} の光が偏波合成器3により合波されて波長合波器2の光入力部207に入力され、波長 λ_{7a} 、 λ_{8a} の光が偏波合成器3により合波されて波長合波器2の光入力部208に入力される。

【0065】また、波長 λ_1 、 λ_2 、 λ_3 、 λ_4 の光はそれぞれ波長合波器2の光出力部203、204、205、206に入力される。

【0066】そうすると、上記の波長合波器2の機能により、各波長 λ_1 、 λ_2 、 λ_3 、 λ_4 の励起光が波長合波器2によって低損失で合波され、波長合波器2の光出力部14から出力される。

【0067】本実施形態例によれば、波長合波器2の光入力側に4つの偏波合成器3を設け、これらの偏波合成器3で合波した光をそれぞれ波長合波器2の対応する光入力部201、202、207、208に入力する構成とすることにより、図13の励起光源装置においては11個必要だったマッハウエング干渉型合波手段6の総数を7個とすることができ、マッハウエング干渉型光合

手段6の接続段数を4段から3段に少なくすることができるために、従来の波長合波器2において問題であった合波光の波長帯域幅狭化の問題を解消し、波長合波器2の挿入損失を従来例に比べて格段に小さくすることができる。

【0068】また、各偏波合成器3による偏波の合波は非常に低損失で行われるものであるために、本実施形態例の励起光源装置は、各励起光源1から出力される励起光を非常に低損失で合波して光出力部14から出力できる優れた励起光源装置とすることができる。

【0069】したがって、本実施形態例の励起光源装置をRaman増幅装置に適用すれば、励起効率と利得平坦性の良好なRaman増幅を可能とすることができる。

【0070】次に、本発明に係る励起光源装置の第2実施形態例について説明する。本第2実施形態例は上記第1実施形態例とほぼ同様に構成されており、本第2実施形態例が上記第1実施形態例と異なる特徴的なことは、レーザダイオード107bから出力する励起光の波長を図4の(c)及び表2に示す波長 λ_{1b} としたことである。

【0071】

【表2】

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波長(nm)	入力ポート	出力ポート
1411	207	λ_{7b}
1418	202	λ_{2b}
1424	209	λ_{5b}
1431	204	λ_{4b}
1438	208	λ_{8b}
1445	201	λ_{1b}
1452	206	λ_{6b}
1459	203	λ_{3b}
1474	205	λ_{2a}
1496	208	λ_{8a}
1503	201	λ_{1b}
1524	207	λ_{7b}

【0072】この波長の光は、図10に示すように、波長 λ_{7b} のピークから2つ離れた低損失ピークの波長である。このように、偏波合成器3によって合波する2つの波長は、光合波器2の光透過特性において低損失の隣り合うピークである必要はなく、偏波合成器3による合波可能な波長帯域内の波長であればよい。

【0073】本第2実施形態例は、以上のように構成されており、本第2実施形態例も上記第1実施形態例と同様の動作により、波長 λ_{1b} 、 λ_{2b} 、 λ_{3b} 、 λ_{4b} 、 λ_{5b} 、 λ_{6b} 、 λ_{7b} 、 λ_{8b} の励起光を低損失で合波することができ、同様の効果を得ることができる。

【0074】図7には、本発明に係る励起光源装置の第3実施形態例の要部構成が示されている。本第3実施形態例は上記第1実施形態例とはほぼ同様に構成されており、本第3実施形態例が上記第1実施形態例と異なる特徴的なことは、図8に示すような、光ファイバ15により形成したマッハツェンダ干渉型合波手段6を複数段接続して波長合波器2を形成したことである。なお、各光ファイバ型マッハツェンダ干渉型合波手段6は、方向性結合器12を溶融型ファイバカブラ4により形成している。

【0075】本第3実施形態例で適用している光ファイバ型のマッハツェンダ干渉型合波手段6は、上記第1実施形態例で適用した光導波回路のマッハツェンダ干渉型合波手段6と同様の機能を有するものであるため、本第3実施形態例も上記第1実施形態例と同様の動作により同様の効果を得ることができる。

【0076】図9には、本発明に係る励起光源装置の第4実施形態例の要部構成が示されている。本第4実施形態例は上記第3実施形態例とはほぼ同様に構成されており、第4実施形態例が上記第3実施形態例と異なる特徴*

$$P_a = 1 - \sin^2(2\pi \cdot n \cdot z / \lambda) \cdots \cdots (4)$$

【0081】

$$P_b = \sin^2(2\pi \cdot n \cdot z / \lambda) \cdots \cdots (5)$$

【0082】ここで、 z は溶融型ファイバカブラ4の結合長である。このように、溶融型ファイバカブラ4は、

*的なことは、マッハツェンダ干渉型合波手段6の代わりに、図10に示すような溶融型ファイバカブラ4を複数段接続して波長合波器2を形成したことである。なお、溶融型ファイバカブラ4は光ファイバ15により形成されている。

20 【0077】溶融型ファイバカブラ4も、マッハツェンダ干渉型合波手段6と同様に、2本の入射側伝送路5a、5bからそれぞれ入射される波長の異なる光を合波して1本の出射側光伝送路5cに伝送する光合波手段として機能するものであるため、本第4実施形態例では、光合波手段として溶融型ファイバカブラ4を採用することにした。

【0078】そして、本第4実施形態例は、上記第1～第3実施形態例におけるマッハツェンダ干渉型合波手段6の接続構成と同様に、第1段に溶融型ファイバカブラ4(4c1～4c4)を複数(4個)並列し、これら第1段の1対ずつの溶融型ファイバカブラ4の光出力をさらに光合波する第2段の溶融型ファイバカブラ4(4b1、4b2)を接続し、これらの溶融型ファイバカブラ4b1、4b2の光出力をさらに光合波する第3段の溶融型ファイバカブラ4(4a)を接続して、前段の対の溶融型ファイバカブラ4の光出力を後段の溶融型ファイバカブラ4でさらに光合波するという如く、溶融型ファイバカブラ4を複数段(3段)に接続して波長合波器2を形成している。

40 【0079】なお、図10に示す溶融型ファイバカブラ4のそれぞれの入射側伝送路5a、5bから入射して出射側伝送路5cから出力される光の規格化パワー特性 P_a 、 P_b は、それぞれ以下のような式で表わされる。

【0080】

それぞれの入射側伝送路5a、5bから入射して出射側伝送路5cから出力される光の規格化パワー特性 P_a 、 P_b を、 \sin 関数で表わすことができるため、低損失で合波できる波長が周期的に現れるようになる。

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【0083】すなわち、溶融型ファイバケーブル4の結合長等を適宜設定することにより、それぞれの溶融型ファイバケーブル4に、溶融型ファイバケーブル4が台波する台波光中心波長の固有の周期を持たせることができるので、マッハツェンダ干渉型台波手段6の設計と同様に溶融型ファイバケーブル4を設計することにより、本第4実施形態例の励起光源装置を構成している。

【0084】本第4実施形態例は以上のように構成されており、本第4実施形態例も上記各実施形態例とほぼ同様の動作により同様の効果を奏することができる。

【0085】なお、本発明は上記実施形態例に限定されることなく、様々な実施形態を取り得る。例えば、上記各実施形態例では、励起光源1の数を12個としたが、励起光源1の数は特に限定されるものでなく適宜設定されるものである。例えば励起光源1の数を16個とした場合には、波長台波器2の全ての光入力部201～208に波長合成器3を接続すれば、上記各実施形態例と同様の波長合成器2を用いて上記各実施形態例と同様の効果を奏する優れた励起光源装置を構成することができる。

【0086】また、励起光源1の出力波長は特に限定されるものでなく、適宜設定されるものであり、波長台波器2を適宜設計し、例えば図3、4に示したような光透過特性に基づいて、低損失で台波できる波長を励起光源1の出力波長として選択することにより、上記各実施形態例と同様の優れた効果を奏する励起光源装置を構成することができる。

【0087】さらに、上記第1～第3実施形態例ではマッハツェンダ干渉型台波手段6を3段に接続し、上記第4実施形態例では溶融型ファイバケーブル4を3段に接続して波長台波器2を形成したが、波長台波器2の構成は特に限定されるものではなく適宜設定されるものである。

【0088】すなわち、マッハツェンダ干渉型台波手段6や溶融型ファイバケーブル4の接続段数を、波長台波器2で台波する波長数に対応させてできる限り少ない段数とすることで、波長台波器2の挿入損失を低減することができる。また、マッハツェンダ干渉型台波手段6や溶融型ファイバケーブル4の代わりに、2本の入射側伝送路からそれぞれ入射される波長の異なる光を台波して1本の出射側光伝送路に伝送する他の光台波手段を適用することもできる。

【0089】例えば、図11には、2本の入射側伝送路からそれぞれ入射される波長の異なる光を台波して1本の出射側光伝送路に伝送する光台波手段を2段に接続して形成した波長台波器2が模式的に示されており、以下、同図を用いて、上記光台波手段による光台波機能を簡単に説明する。

【0090】なお、同図において、それぞれの光台波手段には符号401、402、403を付してあり、これ

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らの光台波手段401、402、403により台波する台波光中心波長はそれぞれ固有の周期を有している。また、 $(n-1)$ 段目に設けられた光台波手段（ここでは $n=2$ であり、1段目の光台波手段401、402）の固有の周期は2段目に設けられた光台波手段403の固有の周期の整数倍と成している。

【0091】ここで、光台波手段403について、ポート305から入力してポート307から出力される光の挿入損失を求めると、図12の(a)の特性線aおよび同図の(b)の特性線aに示すものとなる。すなわち、この場合、光台波手段403において、クロスポートから入力されて台波される台波光中心波長（低損失で台波できる光の中心波長）は、 $\lambda_a, \lambda_b, \lambda_c, \lambda_d, \dots$ となる。なお、光台波手段403のスルーポート（ポート306）から入力されて台波される台波光中心波長は、同図には図示されていないが、 λ_a と λ_b との間の波長、 λ_c と λ_d との間の波長 \dots となるので（図6の(a)参照）光台波手段403の固有の周期は ΔS の半分の周期となる。

【0092】また、光台波手段401について、ポート301から入力してポート305から出力される光の挿入損失を求めると、図12の(a)の特性線bに示すものとなり、この場合、光台波手段401により台波する台波光中心波長は、 $\lambda_a, \lambda_c, \dots$ となる。一方、光台波手段401について、ポート302から入力してポート305から出力される光の挿入損失を求めると、同図の(b)の特性線bに示すものとなり、光台波手段401により台波する台波光中心波長は、 $\lambda_b, \lambda_d, \dots$ となる。すなわち、光台波手段401の固有の周期は ΔS であり、光台波手段403の固有の周期の2倍となっている。

【0093】このように、光台波手段401と光台波手段403の周期を設定し、光台波手段401の後段に光台波手段403を接続することにより、特性線aと特性線bの両方において低挿入損失の波長のみが、ポート307から出力されることになり、同図の(a)の特性線cに示すように、ポート301から入力される光のうち、波長 $\lambda_a, \lambda_c, \dots$ の光がポート307から低損失で出力され、ポート302から入力される光のうち、波長 $\lambda_b, \lambda_d, \dots$ の光がポート307から低損失で出力される。

【0094】したがって、本発明において、波長台波器2は、2本の入射側伝送路からそれぞれ入射される波長の異なる光を台波して1本の出射側光伝送路に伝送する光台波手段を複数段接続して構成し、それぞれの光台波手段により台波する台波光中心波長がそれぞれ固有の周期を有するものとし、 $(n-1)$ 段目に設けられた光台波手段の固有の周期を n 段目に設けられた光台波手段の固有の周期の整数倍と成すことにより、上記各実施形態例と同様の効果を奏することができる。

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【0095】ただし、上記実施形態例のように、上記光合波手段をマッハツェンダ干渉型合波手段6や溶融型ファイバカプラ4により構成すると、これらの作製技術や機能などが周知であるため、波長合波器2の作製等が行ないやすく、上記優れた効果を奏する励起光源装置を確実に形成することができる。

【0096】

【発明の効果】第1の発明によれば、互いに偏波状態と波長が異なる偏波光を偏波合成器により合波してその合波光を波長合波器の1つ以上の光入力部から波長合波器10に入力するので、波長合波器に設ける光入力部の個数を偏波合成器の配設数分だけ少なくすることができ、波長合波器の挿入損失を低減でき、多数の波長の励起光を合波して高出力で出力できる。

【0097】特に、本発明においては、波長合波器は、2本の入射側伝送路からそれぞれ入射される波長の異なる光を合波して1本の出射側伝送路に伝送する光合波手段を複数段接続して形成した第2の発明においては、上記の如く、波長合波器の光入力部の個数を偏波合成器の配設数分だけ少なくすることができ、波長合波器を形成する光合波手段の個数や段数を低減することができ、段数の多い波長合波器において問題であった合波光の波長帯域幅の増大の問題を抑制でき、波長合波器の挿入損失を低減することができる。

【0098】したがって、第1、第2の発明によれば、多数の波長の励起光を合波して高出力で出力できる励起光源装置を提供することが可能となり、それにより、Raman増幅型光増幅器のRaman増幅効率の向上を図ることができる。

【0099】さらに、第3の発明によれば、それぞれの光合波手段により合波する合波光中心波長はそれぞれ固有の周期を有しており、 $(n-1)$ 段目 $(n$ は2以上の整数)に設けられた光合波手段の固有の周期は n 段目に設けられた光合波手段の固有の周期の整数倍と成しているために、複数段接続した光合波手段によって、励起光源からの励起光を低損失で合波でき、上記優れた効果を奏する励起光源装置を確実に形成することができる。

【0100】さらに、第4～第7の発明のように、光合波手段をそれぞれ2つの方向性結合器を備えたマッハツェンダ干渉型合波手段としたり、溶融型ファイバカプラとしたりすることにより、波長合波器を容易に、作製することができ、上記効果を奏する励起光源装置を確実に提供することができる。

【図面の簡単な説明】

【図1】本発明に係る励起光源装置の第1実施形態例を示す要部構成図である。

【図2】上記実施形態例の波長合波器を形成する光導波回路断面構成を示す説明図である。

【図3】上記実施形態例における波長合波器2の光入力部201～204からそれぞれ入力されて光出力部14

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から出力される光の透過特性（損失）をそれぞれ示すグラフである。

【図4】上記実施形態例における波長合波器2の光入力部205～208からそれぞれ入力されて光出力部14から出力される光の透過特性（損失）をそれぞれ示すグラフである。

【図5】マッハツェンダ干渉型合波手段を2段接続して形成される波長合波器の構成を示す説明図である。

【図6】図5に示す波長合波器2を形成するマッハツェンダ干渉型合波手段8a、8bのそれぞれの光透過特性を模式的に示すグラフ（a）、（b）と、光入力部501、502からそれぞれ入力されて光出力部14から出力される光の透過特性を模式的に示すグラフ（c）である。

【図7】本発明に係る励起光源装置の第3実施形態例を示す要部構成図である。

【図8】上記第3実施形態例を構成する光ファイバ型マッハツェンダ干渉型合波手段の構成図である。

【図9】本発明に係る励起光源装置の第4実施形態例を示す要部構成図である。

【図10】上記第4実施形態例を構成する光ファイバ型溶融型ファイバカプラの構成図である。

【図11】2つの入射側伝送路と1つの出射側伝送路を有する光合波手段を2段接続して形成した波長合波器の例を示す説明図である。

【図12】図11に示した波長合波器を構成する光合波手段の光透過特性と、ポート301、302からそれぞれ入力されてポート307から出力される光の透過特性を模式的に示すグラフである。

【図13】従来の励起光源装置の構成例を示す説明図である。

【図14】マッハツェンダ干渉型合波手段の基本構成の説明図である。

【符号の説明】

- 1 励起光源
- 2 波長合波器
- 3 偏波合成器
- 4 溶融型ファイバカプラ
- 5a、5b 入射側伝送路
- 5c 出射側伝送路
- 6 マッハツェンダ干渉型合波手段
- 8 励起光出力ファイバ
- 9 光入力ファイバ
- 10 コア回路
- 12 方向性結合器
- 14 光出力部
- 22 グレーティング（ファイバグレーティング）
- 101a～108b レーザダイオード
- 201～208 光入力部（入力ポート）

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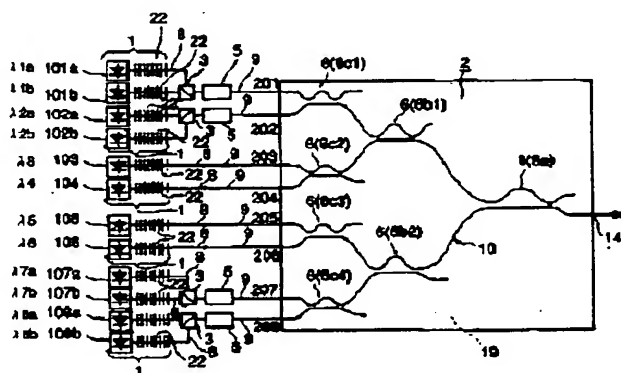
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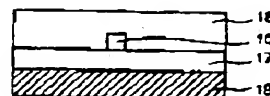
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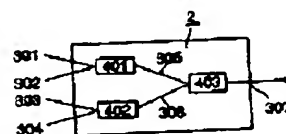
【図 1】



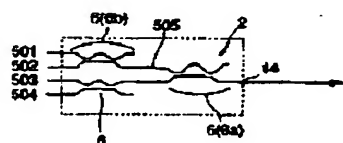
【図 2】



【図 11】



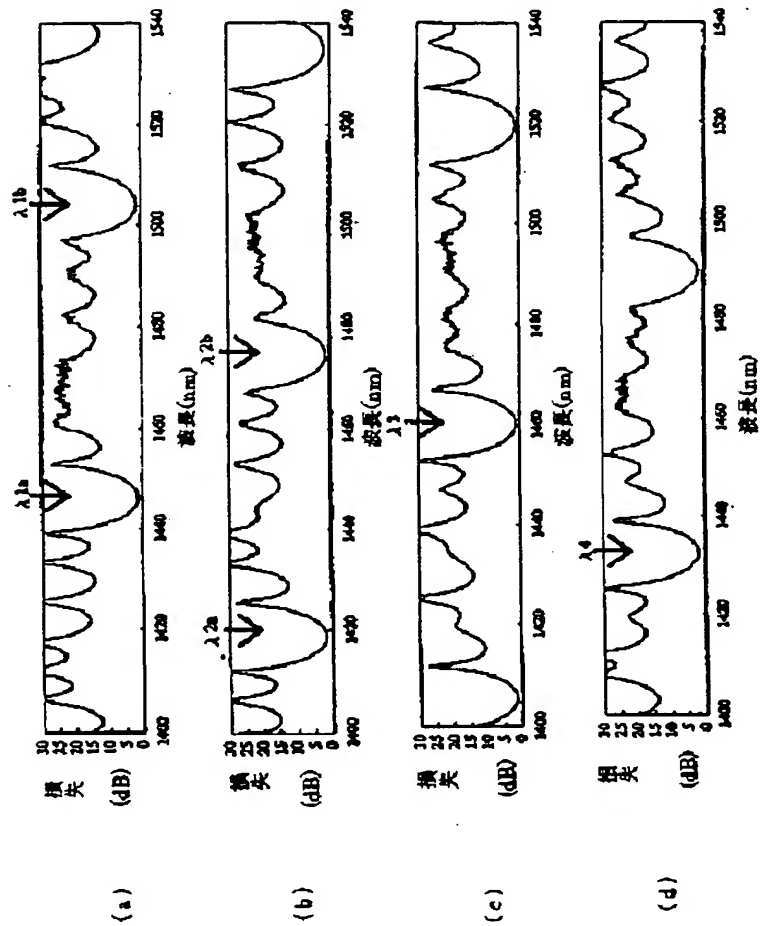
【図 5】



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[図3]



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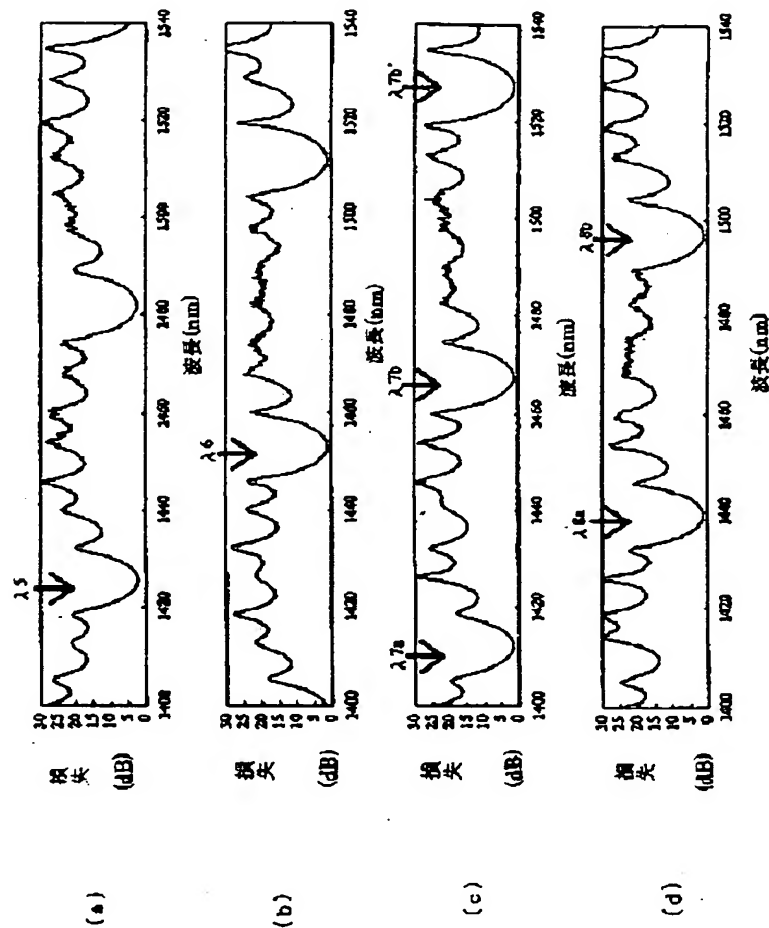
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[図4]



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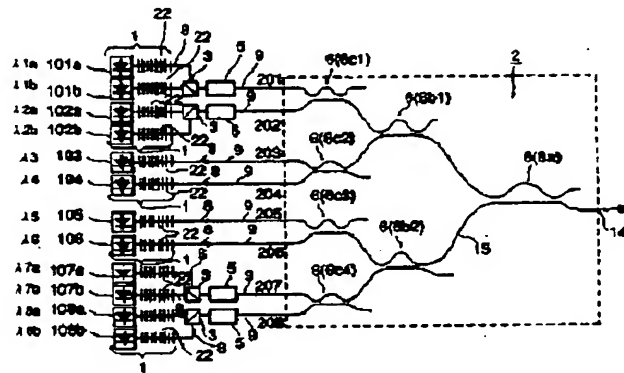
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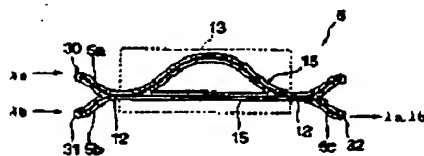
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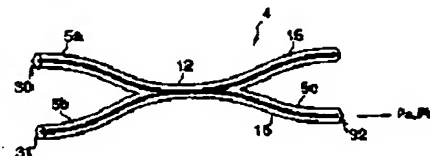
【図7】



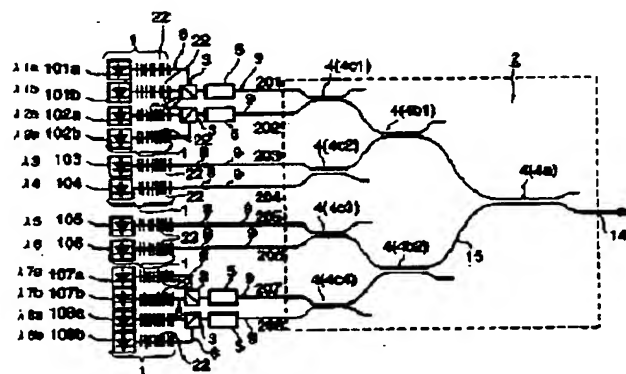
【図8】



【図10】



【図9】



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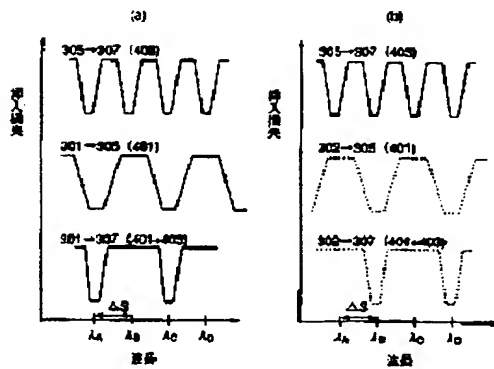
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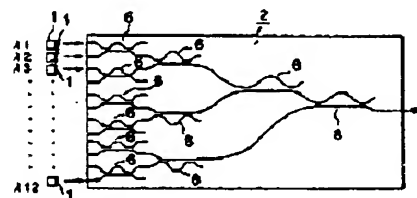
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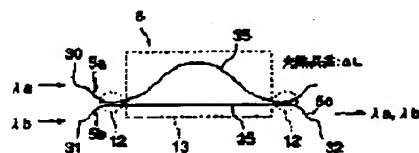
【図12】



【図13】



【図14】



フロントページの続き

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention relates to the excitation light source equipment for light amplifier used by the optical long submarine transmission system of especially a wavelength division multiplex transmission system and a transmission distance etc. about the excitation light source equipment applied to the light amplifier for optical communication.

[0002]

[Description of the Prior Art] In recent years, the wavelength division multiplex transmission system is examined briskly. A wavelength division multiplex transmission system is a system which carries out two or more multiplex [of the lightwave signal of wavelength which is different in one optical fiber as an optical transmission line], and transmits it, and since it can expand transmission capacity by wavelength multiplex, it is in the limelight.

[0003] In the wavelength division multiplex transmission system, making it transmit, a light amplifier being prepared in the middle of an optical transmission line, and amplifying transmission light (lightwave signal) by this light amplifier is performed. As a light amplifier, application of the optical fiber type light amplifier which can make a lightwave signal amplify with light is effective, and, generally the erbium dope optical fiber type light amplifier (EDFA) which used the erbium dope optical fiber is used now.

[0004] By the way, in the above-mentioned wavelength division multiplex transmission system, a wavelength multiplicity is increased, the attempt which is going to increase the amount of transmissions is made, and it considers extending a wavelength-range region as one method of increasing a wavelength multiplicity.

[0005] However, though the above EDFA used as an object for wavelength multiplex transmission systems has only a maximum of 30nm gain band, but lengthens the length of an erbium dope optical fiber even if and generally extends the gain band of EDFA to a long wavelength side, the gain band of EDFA is about a maximum of 60nm. And the gain of EDFA had the wavelength dependency, and since the gain flat nature in a gain band was not good, when EDFA was applied to a wavelength multiplex transmission system, it also had the problem of needing the gain flattening equipment which performs gain flattening of EDFA.

[0006] Then, recently, the Raman amplification type light amplifier using the optical fiber with high nonlinearity has attracted attention as a light amplifier replaced with EDFA. This Raman amplification type light amplifier uses the Raman effect produced when nonlinearity inputs an excitation light strong against a high optical fiber.

[0007] In order for gain flat nature to realize good Raman amplification, when multiplexing two or more excitation light from which wavelength differs mutually [the narrow frequency interval of about 1 THz] is called for and it inputs this multiplexed excitation light into an optical fiber with high nonlinearity, even if it does not use gain flattening equipment, realization of the Raman amplification type light amplifier which has high gain by the wide band 100nm or more can be aimed at.

[0008] As an example of the equipment using Raman amplification, the example which multiplexes the light of the wavelength of 12 which weaves in the wavelength interval of 7.5nm and the wavelength interval of 15nm, and is mutually different in the range with a wavelength of 1405nm - 1510nm is reported to well-known reference "Y.Emori et al. and OFC'99 PD-19."

[0009] The composition of the excitation light source equipment used for the above-mentioned wavelength multiplexing is shown in drawing 13, and is constituted by the excitation light source 1 which outputs the 12 above-mentioned waves (it sets to this drawing and is $\lambda_1, \lambda_2, \dots, \lambda_{12}$) of light, respectively, and the wavelength multiplexing machine 2 which multiplexes the light of the above-mentioned wavelength outputted from each excitation light source 1.

[0010] The wavelength multiplexing machine 2 has two or more Mach TSUENDA interference pattern multiplexing means 6 as shown in drawing 14. As shown in this drawing, the Mach TSUENDA interference pattern multiplexing means 6 is formed of two arms (optical path) 35, multiplexes and transmits the light (this drawing λ_a, λ_b) from which the wavelength by which incidence is carried out from the incidence side [2] transmission lines 5a and 5b, respectively differs to outgoing radiation side [1] transmission-line 5c. In addition, the wavelength multiplexing machine 2 shown in drawing 13 is formed of the optical waveguide circuit, and the above-mentioned arm 35 is formed of the core of an optical waveguide circuit in this case.

[0011] As shown in drawing 14, between the incidence side transmission lines 5a and 5b of the Mach TSUENDA interference pattern multiplexing means 6, and outgoing radiation side transmission-line 5c, two directional couplers 12 and optical-path-length **** 13 inserted into these directional couplers 12 are formed, and the length of two arms 35 differs mutually in this optical-path-length **** 13. The wavelength interval of the light it multiplexes [light] by the Mach TSUENDA interference pattern multiplexing means 6 is determined by the difference of the length of the arm 35 in optical-path-length **** 13.

[0012] As shown in drawing 13, the aforementioned wavelength multiplexing machine 2 has two or more Mach TSUENDA interference pattern multiplexing means 6 of the 1st step of the above-mentioned composition in the incidence side of light (installing six pieces in this drawing). The Mach TSUENDA interference pattern multiplexing means 6 of the 2nd step which carries out optical multiplexing of the optical output of the Mach TSUENDA interference pattern multiplexing means 6 per pair of these 1st step further is connected. A total of 11 Mach TSUENDA interference pattern multiplexing means 6 are connected to four steps, and it is formed so that it may say that optical multiplexing of the optical output of a pair of Mach TSUENDA interference pattern multiplexing means of the preceding paragraph is further carried out with a latter Mach TSUENDA interference pattern multiplexing means.

[0013]

[Problem(s) to be Solved by the Invention] By the way, in a Mach TSUENDA interference pattern multiplexing means 6 to constitute the above wavelength multiplexing machines 2, consideration is required for the design of a directional coupler 12. Loss will become large if joint efficiency by the directional coupler 12 of the wavelength which inputs it into the optical input section (cross port) 30 of the side which intersects the output section 32 of the Mach TSUENDA interference pattern multiplexing means 6 since the joint efficiency of a directional coupler 12 has the wavelength dependency is not made about 50%. In addition, this is indicated by the registration patent No. 2557966.

[0014] However, in the wavelength multiplexing machine 2 of excitation light source equipment as shown in drawing 13, a design whose number of a Mach TSUENDA interference pattern multiplexing means 6 to form the wavelength multiplexing machine 2

period of the optical multiplexing means prepared in the n-th step, and the accomplished composition.

[0021] Furthermore, in addition to the composition of the above 2nd or the 3rd invention, the 4th invention makes the aforementioned optical multiplexing means a means to solve a technical problem with the composition made into the Mach TSUENDA interference pattern multiplexing means equipped with two directional couplers, respectively.

[0022] Furthermore, in addition to the composition of invention of the above 4th, the 5th invention makes the aforementioned directional coupler a means to solve a technical problem with the composition used as the melting type fiber coupler.

[0023] Furthermore, in addition to the composition of invention of the above 4th, the 6th invention makes the aforementioned Mach TSUENDA interference pattern multiplexing means a means to solve a technical problem with the composition formed by the optical waveguide circuit.

[0024] Furthermore, in addition to the composition of the above 2nd or the 3rd invention, the 7th invention makes the aforementioned optical multiplexing means a means to solve a technical problem with the composition used as the melting type fiber coupler.

[0025] In the one or more optical input sections of the wavelength multiplexing machine which multiplexes the light of two or more mutually different wavelength in this invention of the above-mentioned composition Since the polarization composition machine which multiplexes two polarization light from which a polarization state differs mutually is connected and the two excitation light sources which output the polarization light from which a polarization state and wavelength differ mutually are connected to this polarization composition machine It is multiplexed with a polarization composition vessel and the polarization light outputted from the two excitation light sources, respectively is inputted into a wavelength multiplexing machine.

[0026] Although the number of the optical input section prepared in a wavelength multiplexing machine was required in the composition of conventional excitation light source equipment as shown in drawing 13 the number of waves (this drawing 12 pieces) it multiplexes [number] with a wavelength multiplexing vessel Since the polarization light from which a polarization state and wavelength differ mutually is multiplexed with a polarization composition vessel in this invention and the multiplexing light is inputted into a wavelength multiplexing machine from the one or more optical input sections of a wavelength multiplexing machine For example, as shown in drawing 1 , when the number of excitation light source equipment is the same, it becomes possible to lessen the number of the optical input section prepared in a wavelength multiplexing machine only several arrangement minutes of a polarization composition machine.

[0027] If what connects two or more steps and forms optical multiplexing meanses, such as for example, a Mach TSUENDA interference pattern multiplexing means, is generally used and the number of the optical input section increases in this kind of wavelength multiplexing machine, especially a wavelength multiplexing machine it -- following -- the number and the number of stages of an optical multiplexing means -- many -- not carrying out, although it did not obtain but the increase in the insertion loss of the wavelength multiplexing machine accompanying it was a problem Since the number of the optical input section prepared in a wavelength multiplexing machine can be lessened only several arrangement minutes of a polarization composition machine in this invention the number and the number of stages of an optical multiplexing means which form a wavelength multiplexing machine can be reduced, the problem of the formation of wavelength-range region narrow width of face of the multiplexing light which was a problem can be reduced in a wavelength multiplexing machine with many number of stageses, the insertion loss of a wavelength multiplexing machine is boiled markedly, and reduction becomes possible

there are 11 pieces and four steps of number of stages, the wavelength it multiplexes [wavelength] with the Mach TSUENDA interference pattern multiplexing means 6 whose number is one becomes complicated, and makes the above-mentioned joint efficiency about 50% is difficult.

[0015] Moreover, the wavelength multiplexing machine 2 applied to the above-mentioned excitation light source equipment also has many connection number of stages of the Mach TSUENDA interference pattern multiplexing means 6. Since the bandwidth of each wavelength it multiplexes [wavelength] with the wavelength multiplexing vessel 2 becomes narrow as the number of stages of the Mach TSUENDA interference pattern multiplexing means 6 increases, In the wavelength multiplexing machine 2 with many connection number of stages of the Mach TSUENDA interference pattern light multiplexing machine 6, since it becomes impossible for every [of the spectral band width (bandwidth) of each excitation light / a part] to penetrate the wavelength multiplexing machine 2 and the insertion loss of the wavelength multiplexing machine 2 size-comes to come in connection with it, multiplexing excitation luminous intensity will decrease.

[0016] Therefore, the Raman amplification type light amplifier of the above-mentioned proposal using this wavelength multiplexing machine 2 was not able to raise Raman amplification efficiency.

[0017] this invention is accomplished in order to solve the above-mentioned technical problem, and the purpose is in offering the excitation light source equipment which multiplexes and can output the excitation light of much wavelength by high power so that improvement in the Raman amplification efficiency of a Raman amplification type light amplifier can be aimed at.

[0018]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, this invention has the following composition and makes it the The means for solving a technical problem. Namely, the 1st invention has the wavelength multiplexing machine which multiplexes the light of two or more mutually different wavelength. The optical output section of the polarization composition machine which multiplexes two polarization light from which a polarization state differs mutually is connected to the one or more optical input sections of this wavelength multiplexing machine. It is considering as a means by which the two excitation light sources which output the polarization light from which a polarization state and wavelength differ mutually to the optical input section of this polarization composition machine solve a technical problem with the composition connected, respectively.

[0019] Moreover, it has two or more optical multiplexing meanses of the 1st step for the 2nd invention to multiplex the light from which the wavelength to which incidence of the aforementioned wavelength multiplexing machine is carried out from an incidence side [2] transmission line, respectively differs in addition to the composition of invention of the above 1st, and to transmit to one outgoing radiation photometry transmission line. So that the optical multiplexing means of the 2nd step which carries out optical multiplexing of the optical output of the optical multiplexing means per pair of these 1st step further may be connected and the optical output of a pair of optical multiplexing means of the preceding paragraph may be referred to as carrying out optical multiplexing further with a latter optical multiplexing means It is considering as a means to solve a technical problem with the composition which connects an optical multiplexing means to two or more steps, and is formed.

[0020] Furthermore, the multiplexing light center wavelength the 3rd invention multiplexes [wavelength] by the optical multiplexing means of each above in addition to the composition of invention of the above 2nd has the peculiar period, respectively. (n-1) The peculiar period of the optical multiplexing means prepared in eye the stage (n is two or more integers) is made into a means to solve a technical problem with the integral multiple of the peculiar

[0028] Therefore, this invention becomes possible [offering the excitation light source equipment which multiplexes and can output the excitation light of much wavelength by high power], and, thereby, becomes possible [aiming at improvement in the Raman amplification efficiency of a Raman amplification type light amplifier].

[0029]

[Embodiments of the Invention] Hereafter, the form of operation of this invention is explained based on a drawing. In addition, in explanation of this example of an operation form, the same sign is given to the same name portion as the conventional example, and the duplication explanation is omitted. The example of the 1st operation form of the excitation light source equipment concerning this invention is shown in drawing 1.

[0030] As shown in this drawing, the excitation light source equipment of this example of an operation form has the wavelength multiplexing machine 2 which multiplexes the excitation light source 1 of plurality (this drawing 12 pieces) which outputs the excitation light of mutually different wavelength ($\lambda 1a$, $\lambda 1b$, $\lambda 2a$, ... $\lambda 8b$), and the light of two or more mutually different wavelength. each excitation light source 1 -- laser diodes 101a and 102b and ... it has 108b and the excitation optical output fiber 8, and the grating (fiber grating) 22 which reflects the light of the above-mentioned wavelength mutually different, respectively is formed in each excitation optical output fiber 8

[0031] The optical output section of the polarization composition machine 3 which multiplexes two polarization light from which a polarization state differs mutually through the optical input fiber 9 and a depolarizer 5, respectively is connected to the one or more (this drawing four) optical input sections (input port) 201,202,207,208 of the wavelength multiplexing machine 2. The optical output section of the two excitation light sources 1 which output the polarization light from which a polarization state and wavelength differ mutually, respectively is connected to the optical input section of these polarization composition machines 3, respectively.

[0032] The two excitation light sources 1 connected to each polarization composition machine 3 are constituted so that one of these may output a linearly polarized wave and another side may output a horizontally polarized wave. Moreover, since the polarization composition machine 3 has the function which multiplexes the polarization of the band containing the light of the wavelength outputted from the two excitation light sources 1 which correspond, respectively with low loss, composition of the above-mentioned horizontally polarized wave with the polarization composition machine 3 and a vertically polarized wave is performed very much with low loss.

[0033] Furthermore, in this example of an operation form, polarization dependency loss of the wavelength multiplexing machine 2 has suppressed the influence which it has on multiplexing light with the wavelength multiplexing machine 2 by making into a non-polarization state the polarization state of the excitation light of the above-mentioned linearly polarized wave and a horizontally polarized wave which carried out polarization composition with the polarization composition vessel 3 by forming a depolarizer 5 in the output side of the polarization composition machine 3.

[0034] Every one excitation light source 1 is connected to the optical remaining input section (input port) 203,204,205,206 of the aforementioned wavelength multiplexing machine 2 through the optical input fiber 9, respectively. In addition, this example of an operation form is also changing into the non-polarization state the light from the excitation light source 1 connected to the optical input section 203,204,205,206.

[0035] $\lambda 1a$ from which the reflected light wavelength of the aforementioned grating 22 currently formed in each excitation light source 1 differs mutually, $\lambda 1b$, $\lambda 2a$, and ... the laser diodes 101a and 102b to which it is 12 kinds of wavelength to $\lambda 8b$, and each grating 22 corresponds, and ... it functions as an external resonator of 108b Thus, by operating

a grating 22 as an external resonator, the output of the reflected light wavelength (λ_1 , λ_2 , ..., λ_8) of each grating 22 is enabled by narrow oscillation-spectrum width of face from each excitation light source 1, and the output of each excitation light source 1 is made stable.

[0036] as shown in drawing 2, using the flame depositing method (N.Takato et al, J.Lightwave Tech., vol16, and pp.1003-1010 -- refer to 1988 times), the aforementioned wavelength multiplexing machine 2 forms the lower clad layer 18 and the core circuit 10 in order on a silicon substrate 19, and is formed of the optical waveguide circuit which embedded the core circuit 10 in the up clad layer 17 further [for example,] In addition, detailed explanation of the formation method of the optical waveguide circuit by the flame depositing method is omitted.

[0037] As shown in drawing 1, the core circuit 10 has two or more Mach TSUENDA interference pattern multiplexing means 6 as an optical multiplexing means to form the wavelength multiplexing machine 2, and is carrying out two or more (four pieces) side-by-side installation of the Mach TSUENDA interference pattern multiplexing means 6 (6c1 to 6c4) of the 1st step at the optical input section 201-208 side.

[0038] Moreover, the Mach TSUENDA interference pattern multiplexing means 6 (six b1, six b2) of the 2nd step which carries out optical multiplexing of the optical output of the Mach TSUENDA interference pattern multiplexing means 6 per pair further among these Mach TSUENDA interference pattern multiplexing means 6 is connected, and it is a pair of Mach TSUENDA interference pattern multiplexing means 6 (in this case) of the preceding paragraph. So that it may say that optical multiplexing of the optical output of 6c1 to 6c4 is further carried out with the latter Mach TSUENDA interference pattern multiplexing means 6 (six b1, six b2) in this example of an operation form [in this case] A total of seven Mach TSUENDA interference pattern multiplexing means 6 (6a-6c4) are connected to two or more steps (here three steps), and the core circuit 10 is formed.

[0039] Moreover, in this example of an operation form, the multiplexing light center wavelength it multiplexes [wavelength] by each Mach TSUENDA interference pattern multiplexing means 6 has the peculiar period, respectively, and the peculiar period of the Mach TSUENDA interference pattern multiplexing means 6 prepared in eye the stage (n-1) (n is two or more integers) is accomplished with the integral multiple of the peculiar period of the Mach TSUENDA interference pattern multiplexing means 6 prepared in the n-th step.

[0040] In addition, the 2nd step of Mach TSUENDA interference pattern multiplexing means six b1 and the peculiar period of six b2 are specifically accomplished with the double precision of the peculiar period of the 3rd step of Mach TSUENDA interference pattern multiplexing means 6a. Furthermore, the peculiar period of the Mach TSUENDA interference pattern multiplexing means 6c1 to 6c4 prepared in the 1st step is accomplished with the double precision of the Mach TSUENDA interference pattern multiplexing means six b1 prepared in the 2nd step, and the peculiar period of six b2.

[0041] The period with the peculiar multiplexing light center wavelength it multiplexes [wavelength] by the above-mentioned Mach TSUENDA interference pattern multiplexing means 6 is determined by the design of the wavelength multiplexing machine 2 shown below. Hereafter, the design method of the wavelength multiplexing machine 2 in this example of an operation form is explained briefly.

[0042] Like the above, light wave length (multiplexing light center wavelength it can multiplex [wavelength] with low loss by Mach TSUENDA interference pattern multiplexing means 6) λ_a outputted with low loss from outgoing radiation side transmission-line 5c among the light which carries out incidence from each incidence side transmission lines 5a and 5b of the Mach TSUENDA interference pattern multiplexing means 6 which the basic composition of the Mach TSUENDA interference pattern multiplexing means 6 is shown to

drawing 14 , and is shown in this drawing, and λ_{ab} are wavelength expressed with the respectively following formulas.

[0043] $\lambda_a = n \cdot \Delta L / m$ (1)

[0044]

$\lambda_{ab} = n \cdot \Delta L / (m + 1/2)$ (2)

[0045] Here, n is [an optical-path-length difference and m of the refractive index of an optical transmission line and ΔL] integers. In addition, the optical input section 30 of incidence side transmission-line 5a which crosses to outgoing radiation side transmission-line 5c and the optical output section 32 is called cross port like the above, and the optical input section 31 of incidence side transmission-line 5b not crossing is called through port.

[0046] From a formula (1) and (2), like a formula (3), the multiplexing wavelength of the Mach TSUENDA interference pattern multiplexing means 6 sets the velocity of light to c , and appears periodically in fixed frequency interval Δf .

[0047]

$\Delta f = c / (2n \cdot \Delta L)$ (3)

[0048] The example of a light-transmission wavelength property of the Mach TSUENDA interference pattern multiplexing means 6 shown in drawing 14 is shown in (a) of drawing 6 . In the Mach TSUENDA interference pattern multiplexing means 6 it is shown in a formula (3) -- it needs -- etc., as it is frequency interval Δf , for example, is shown in the ultimate lines a and b of (a) of drawing 6 . The peak of low loss appears, and as shown in ultimate lines a, the low loss peak wavelength in the transmitted wave length property of the light inputted from a cross port (it sets to drawing 14 and is the optical input section 30) becomes λ_{aa1} , λ_{aa2} , λ_{aa3} , λ_{aa4} , and ... (a peak frequency interval is $2\Delta f$). In addition, the ultimate lines b of (a) of this drawing show the transmitted wave length property of the light inputted from a through port (it sets to drawing 14 and is the optical input section 31).

[0049] As shown in drawing 5 , supposing it forms this Mach TSUENDA interference pattern multiplexing means 6 in the output section 14 side of the wavelength multiplexing machine 2 as Mach TSUENDA interference pattern multiplexing means 6a Mach TSUENDA interference pattern multiplexing means 6a will multiplex, and can output the light of the wavelength λ_{aa1} inputted into Mach TSUENDA interference pattern multiplexing means 6a from the optical input section 505 (cross port), λ_{aa2} , λ_{aa3} , λ_{aa4} , and ... from the optical output section 14.

[0050] Moreover, as shown in this drawing, when Mach TSUENDA interference pattern multiplexing means 6b is connected to the preceding paragraph of Mach TSUENDA interference pattern multiplexing means 6a, By designing optical-path-length difference ΔL in Mach TSUENDA interference pattern multiplexing means 6b of the side (preceding paragraph) to connect in the half of the optical-path-length difference in latter Mach TSUENDA interference pattern multiplexing means 6a Let frequency interval Δf of Mach TSUENDA interference pattern multiplexing means 6b of the preceding paragraph be the double precision of latter Mach TSUENDA interference pattern multiplexing means 6a. If it does so, the light-transmission property of Mach TSUENDA interference pattern multiplexing means 6b will turn into a property shown in (b) of drawing 6 .

[0051] In addition, the transmitted wave length property of light that ultimate lines a are inputted in (b) of drawing 6 from a cross port (it sets to drawing 5 and is the optical input section 501), Ultimate lines b show the transmitted wave length property of the light inputted from a through port (it sets to drawing 5 and is the optical input section 502). Mach TSUENDA interference pattern multiplexing means 6b It will multiplex and the light of the wavelength λ_{aa1} inputted from the optical input section 501, λ_{aa3} , and ... and the light of the wavelength λ_{aa2} inputted from the optical input section 502, λ_{aa4} , and ... can be outputted.

[0052] And by combining Mach TSUENDA interference pattern multiplexing means 6b and Mach TSUENDA interference pattern multiplexing means 6a, the transmitted wave length property of the light which it is inputted from the optical input section 501, and is outputted from the optical output section 14 turns into a property shown in the ultimate lines a of (c) of drawing 6, with low loss, it will be multiplexed and the light of wavelength λ_{a1} , λ_{a3} , and ... will be outputted. Moreover, the transmitted wave length property of the light which it is inputted from the optical input section 502, and is outputted from the optical output section 507 turns into a property shown in the ultimate lines b of (c) of drawing 6, with low loss, it will be multiplexed and the light of wavelength λ_{a2} , λ_{a4} , and ... will be outputted.

[0053] Moreover, when connecting the Mach TSUENDA interference pattern multiplexing means 6 to the preceding paragraph of Mach TSUENDA interference pattern multiplexing means 6b further, like the above, the peculiar period of the Mach TSUENDA interference pattern multiplexing means 6 is determined, it is made to correspond to it and the optical-path-length difference is determined.

[0054] On the occasion of the design of the wavelength multiplexing machine 2, by thus, the Mach TSUENDA interference pattern multiplexing means 6 by the side of the optical output section 14 among Mach TSUENDA interference pattern multiplexing means 6 to constitute the wavelength multiplexing machine 2 So that the output light from all the excitation light sources 1 linked to the wavelength multiplexing machine 2 can be multiplexed A period with the peculiar multiplexing light center wavelength it multiplexes [wavelength] by the Mach TSUENDA interference pattern multiplexing means 6 (frequency interval Δf) is determined. It is made to correspond to this period, optical-path-length difference ΔL of the Mach TSUENDA interference pattern multiplexing means 6 is determined, and the peculiar period and the optical-path-length difference are determined one by one as mentioned above about a Mach TSUENDA interference pattern multiplexing means 6 to connect with the preceding paragraph of this Mach TSUENDA interference pattern multiplexing means 6.

[0055] If it does so, the wavelength multiplexing machine 2 which can multiplex the output light from all the excitation light sources 1 linked to the wavelength multiplexing machine 2 with low loss will be formed.

[0056] It was made for a light-transmission property in case the light which determined the multiplexing light center wavelength it multiplexes [wavelength] by each Mach TSUENDA interference pattern multiplexing means 6 to form the wavelength multiplexing machine 2 as mentioned above, for example, was inputted from the optical input section 201 of drawing 1 is outputted from the optical output section 14 through the Mach TSUENDA interference pattern multiplexing means 6c1, 6b1, and 6a in order to turn into a property shown in (a) of drawing 3 in this example of an operation form. When the light of wavelength λ_{a1} and λ_{a2} is inputted from the optical input section 201, with the wavelength multiplexing vessel 2, it is multiplexed with low loss and the light of such wavelength is outputted from the optical output section 14, so that clearly from this property.

[0057] A light-transmission property in case similarly the light inputted from the optical input section 202 is outputted from the optical output section 14 through the Mach TSUENDA interference pattern multiplexing means 6c1, 6b1, and 6a in order It becomes what is shown in (b) of this drawing, and in this example of an operation form, when the light of wavelength λ_{a2a} and λ_{a2b} is inputted from the optical input section 202, with the wavelength multiplexing vessel 2, it is multiplexed with low loss and the light of such wavelength is outputted from the optical output section 14.

[0058] Moreover, the light-transmission property in case the light inputted from the optical input section 203 and the light inputted from the optical input section 204 are outputted from the optical output section 14 through the Mach TSUENDA interference pattern multiplexing

means 6c2, six b1, and 6a in order, respectively is similarly shown in (c) of this drawing, and (d). In this example of an operation form, when the light of wavelength $\lambda 3$ is inputted from the optical input section 203 and the light of wavelength $\lambda 4$ is inputted from the optical input section 204, with the wavelength multiplexing vessel 2, it is multiplexed with low loss and the light of such wavelength is outputted from the optical output section 14.

[0059] Furthermore, the light-transmission property in case the light inputted from the optical input section 205 and the light inputted from the optical input section 206 are outputted to (a) of drawing 4 and (b) from the optical output section 14 through the Mach TSUENDA interference pattern multiplexing means 6c3, six b2, and 6a in order, respectively is shown. In this example of an operation form, when the light of wavelength $\lambda 5$ is inputted from the optical input section 205 and the light of wavelength $\lambda 6$ is inputted from the optical input section 206, with the wavelength multiplexing vessel 2, it is multiplexed with low loss and the light of such wavelength is outputted from the optical output section 14.

[0060] Furthermore, the light-transmission property in case the light inputted from the optical input section 207 is outputted to (c) of this drawing from the optical output section 14 through the Mach TSUENDA interference pattern multiplexing means 6c4, six b2, and 6a in order is shown. In this example of an operation form, when the light of wavelength $\lambda 7a$ and $\lambda 7b$ is inputted from the optical input section 207, with the wavelength multiplexing vessel 2, it is multiplexed with low loss and the light of such wavelength is outputted from the optical output section 14.

[0061] Furthermore, the light-transmission property in case the light inputted from the optical input section 208 is outputted to (d) of this drawing from the optical output section 14 through the Mach TSUENDA interference pattern multiplexing means 6c4, six b2, and 6a in order is shown. In this example of an operation form, when the light of wavelength $\lambda 8a$, and $\lambda 8b$ is inputted from the optical input section 208, with the wavelength multiplexing vessel 2, it is multiplexed with low loss and the light of such wavelength is outputted from the optical output section 14.

[0062] in addition -- each -- wavelength $\lambda 1a$, $\lambda 1b$, and ... the concrete value of $\lambda 8b$ is a value shown in Table 1

[0063]

[Table 1]

波長(nm)	入力ポート	波長符号
1411	207	$\lambda 7a$
1418	202	$\lambda 2a$
1424	205	$\lambda 5$
1431	204	$\lambda 4$
1438	208	$\lambda 8a$
1445	201	$\lambda 1a$
1452	206	$\lambda 6$
1459	203	$\lambda 3$
1466	207	$\lambda 7b$
1474	202	$\lambda 2b$
1496	208	$\lambda 8b$
1503	201	$\lambda 1b$

[0064] Wavelength $\lambda 1a$ which this example of an operation form is constituted as mentioned above, and is outputted from the excitation light source 1, It is multiplexed with the polarization composition vessel 3, and the light of $\lambda 1b$ is inputted into the optical input section 201 of the wavelength multiplexing machine 2. Similarly, it is multiplexed with

the polarization composition vessel 3, and the light of wavelength λ_{2a} and λ_{2b} is inputted into the optical input section 202 of the wavelength multiplexing machine 2. It is multiplexed with the polarization composition vessel 3, and the light of wavelength λ_{7a} and λ_{7b} is inputted into the optical input section 207 of the wavelength multiplexing machine 2, it is multiplexed with the polarization composition vessel 3, and the light of wavelength λ_{8a} and λ_{8b} is inputted into the optical input section 208 of the wavelength multiplexing machine 2.

[0065] Moreover, the light of wavelength λ_3 , λ_4 , λ_5 , and λ_6 is inputted into the optical input section 203, 204, 205, 206 of the wavelength multiplexing machine 2, respectively.

[0066] the function of the wavelength multiplexing machine 2 right [that], then above-mentioned -- each -- wavelength λ_{1a} , λ_{1b} , and ... with the wavelength multiplexing vessel 2, it is multiplexed with low loss and the excitation light of λ_{8b} is outputted from the optical output section 14 of the wavelength multiplexing machine 2

[0067] According to this example of an operation form, four polarization composition machines 3 are formed in the optical input side of the wavelength multiplexing machine 2. By considering as the composition which inputs the light it multiplexed [light] with these polarization composition vessels 3 into the optical input section 201, 202, 207, 208 to which the wavelength multiplexing machine 2 corresponds, respectively Since the total of the Mach TSUENDA interference pattern multiplexing means 6 which was required for 11 pieces can be made into seven pieces in the excitation light source equipment of drawing 13 and the connection number of stages of the Mach TSUENDA interference pattern light multiplexing means 6 can be made few to three steps from four steps in the conventional wavelength multiplexing machine 2, the problem of the formation of wavelength-range region narrow width of face of the multiplexing light which was a problem is solved, and the insertion loss of the wavelength multiplexing machine 2 can be markedly boiled compared with the conventional example, and can be made small

[0068] Moreover, since it is that to which multiplexing of polarization with each polarization composition machine 3 is performed very much with low loss, let the excitation light source equipment of this example of an operation form be the outstanding excitation light source equipment which multiplexes with low loss very much and can output the excitation light outputted from each excitation light source 1 from the optical output section 14.

[0069] Therefore, if the excitation light source equipment of this example of an operation form is applied to a Raman amplifying device, Raman amplification with good excitation efficiency and gain flat nature can be enabled.

[0070] Next, the example of the 2nd operation form of the excitation light source equipment concerning this invention is explained. The example of a **** 2 operation form is constituted almost like the above-mentioned example of the 1st operation form, and the characteristic thing which the example of a **** 2 operation form differs from the above-mentioned example of the 1st operation form is having considered as wavelength λ_{7b} which shows the wavelength of the excitation light outputted from laser diode 107b in (c) and Table 2 of drawing 4.

[0071]

[Table 2]

波長(nm)	入力ポート	波長符号
1411	207	$\lambda 7a$
1418	202	$\lambda 2a$
1424	205	$\lambda 5$
1431	204	$\lambda 4$
1438	208	$\lambda 8a$
1445	201	$\lambda 1a$
1452	206	$\lambda 6$
1459	203	$\lambda 3$
1474	202	$\lambda 2b$
1496	208	$\lambda 8b$
1503	201	$\lambda 1b$
1526	207	$\lambda 7b'$

[0072] The light of this wavelength is the wavelength of the low loss peak which separated two from the peak of wavelength $\lambda 7a$, as shown in this drawing. Thus, two wavelength it multiplexs [wavelength] with the polarization composition vessel 3 does not need to be peaks which low loss adjoins in the light-transmission property of the optical multi/demultiplexer 2, and should just be the wavelength of the area within a wavelength range with the polarization composition machine 3 which can be multiplexed.

[0073] the example of a **** 2 operation form is constituted as mentioned above -- having -- **** -- the operation as the above-mentioned example of the 1st operation form also with the same example of a **** 2 operation form -- wavelength $\lambda 1a$, $\lambda 1b$, and ... the excitation light of $\lambda 7a$, $\lambda 7b'$, $\lambda 8a$, and $\lambda 8b$ can be multiplexed with low loss, and the same effect can be done so

[0074] The important section composition of the example of the 3rd operation form of the excitation light source equipment concerning this invention is shown in drawing 7. The example of a **** 3 operation form is constituted almost like the above-mentioned example of the 1st operation form, and the characteristic thing which the example of a **** 3 operation form differs from the above-mentioned example of the 1st operation form is having connected two or more steps of Mach TSUENDA interference pattern multiplexing means 6 formed by the optical fiber 15 as shown in drawing 8, and having formed the wavelength multiplexing machine 2. In addition, each optical fiber type Mach TSUENDA interference pattern multiplexing means 6 forms the directional coupler 12 with the melting type fiber coupler.

[0075] Since an optical fiber type Mach TSUENDA interference pattern multiplexing means 6 to by_ which it has applied in the example of a **** 3 operation form is what has the same function as the Mach TSUENDA interference pattern multiplexing means 6 of the optical waveguide circuit applied in the above-mentioned example of the 1st operation form, it can do the same effect so by the operation as the above-mentioned example of the 1st operation form also with the same example of a **** 3 operation form.

[0076] The important section composition of the example of the 4th operation form of the excitation light source equipment concerning this invention is shown in drawing 9. The example of a **** 4 operation form is constituted almost like the above-mentioned example of the 3rd operation form, and the characteristic thing which the example of the 4th operation form differs from the above-mentioned example of the 3rd operation form is having connected two or more steps of melting type fiber couplers 4 as shown in drawing 10 instead of the Mach TSUENDA interference pattern multiplexing means 6, and having formed the wavelength multiplexing machine 2. In addition, the melting type fiber coupler 4 is formed of

the optical fiber 15.

[0077] Since it was what functions as an optical multiplexing means to multiplex and to transmit the light from which the wavelength by which incidence is carried out from the incidence side [2] transmission lines 5a and 5b, respectively differs like the Mach TSUENDA interference pattern multiplexing means 6 to one outgoing radiation photometry transmission-line 5c, the melting type fiber coupler 4 was also made to apply the melting type fiber coupler 4 as an optical multiplexing means in the example of a **** 4 operation form.

[0078] and the example of a **** 4 operation form like the connection composition of the Mach TSUENDA interference pattern multiplexing means 6 in the above 1st - the example of the 3rd operation form Two or more (four pieces) side-by-side installation of the melting type fiber coupler 4 (4c1 to 4c4) is carried out in the 1st step. The melting type fiber coupler 4 (four b1, four b2) of the 2nd step which carries out optical multiplexing of the optical output of the melting type fiber coupler 4 per pair of these 1st step further is connected. These melting type fiber couplers four b1 and the melting type fiber coupler 4 (4a) of the 3rd step which carries out optical multiplexing of the optical output of four b2 further are connected. The melting type fiber coupler 4 is connected to two or more steps (three steps), and the wavelength multiplexing machine 2 is formed so that it may say that optical multiplexing of the optical output of a pair of melting type fiber coupler 4 of the preceding paragraph is further carried out with the latter melting type fiber coupler 4.

[0079] In addition, the standardization power characteristics Pa and Pb of the light which carries out incidence from each incidence side transmission lines 5a and 5b of the melting type fiber coupler 4 shown in drawing 10 , and is outputted from outgoing radiation side transmission-line 5c are expressed with the respectively following formulas.

[0080]

$$Pa=1-\sin^2(2\pi n z/\lambda) \dots (4)$$

[0081]

$$Pb=\sin^2(2\pi n z/\lambda) \dots (5)$$

[0082] Here, z is the bond length of the melting type fiber coupler 4. Thus, since it can be made to express with a sin function the standardization power characteristics Pa and Pb of the light which carries out incidence of the melting type fiber coupler 4 from each incidence side transmission lines 5a and 5b, and is outputted from outgoing radiation side transmission-line 5c, the wavelength it can multiplex [wavelength] with low loss comes to appear periodically.

[0083] That is, since a period with the peculiar multiplexing light center wavelength the melting type fiber coupler 4 multiplexes [wavelength] can be given to each melting type fiber coupler 4 by setting up suitably the bond length of the melting type fiber coupler 4 etc., the excitation light source equipment of the example of a **** 4 operation form is constituted by designing the melting type fiber coupler 4 like the design of the Mach TSUENDA interference pattern multiplexing means 6.

[0084] The example of a **** 4 operation form is constituted as mentioned above, and can do the same effect so by the operation as each above-mentioned example of an operation form also with the almost same example of a **** 4 operation form.

[0085] In addition, this invention is not limited to the above-mentioned example of an operation form, and can take the mode of various operations. For example, in each above-mentioned example of an operation form, although the number of the excitation light sources 1 was made into 12 pieces, especially the number of the excitation light sources 1 is not limited, and is set up suitably. For example, if the polarization composition machine 3 is connected to all the optical input sections 201-208 of the wavelength multiplexing machine 2 when the number of the excitation light sources 1 is made into 16 pieces, the outstanding excitation light source equipment which does so the same effect as each above-mentioned example of an operation form using the same wavelength multiplexing machine 2 as each

above-mentioned example of an operation form can constitute.

[0086] Moreover, especially the output wavelength of the excitation light source 1 can constitute the excitation light source equipment which does so the same outstanding effect as each above-mentioned example of an operation form by choosing the wavelength it can multiplex [wavelength] with low loss as output wavelength of the excitation light source 1 based on a light-transmission property as not limited, set up suitably, and designed the wavelength multiplexing machine 2 suitably, for example, shown in drawing 3 and 4.

[0087] Furthermore, although the Mach TSUENDA interference pattern multiplexing means 6 was connected to three steps, the melting type fiber coupler 4 was connected to three steps in the above-mentioned example of the 4th operation form and the wavelength multiplexing machine 2 was formed in the above 1st - the example of the 3rd operation form, especially the composition of the wavelength multiplexing machine 2 is not limited, and is set up suitably.

[0088] That is, the insertion loss of the wavelength multiplexing machine 2 can be reduced by making the connection number of stages of the Mach TSUENDA interference pattern multiplexing means 6 or the melting type fiber coupler 4 equivalent to the number of wavelength it multiplexes [number] with the wavelength multiplexing vessel 2, and making it into the fewest possible number of stages. Moreover, other optical multiplexing meanses to multiplex and to transmit the light from which the wavelength by which incidence is carried out from an incidence side [2] transmission line, respectively differs instead of the Mach TSUENDA interference pattern multiplexing means 6 or the melting type fiber coupler 4 to one outgoing radiation photometry transmission line are also applicable.

[0089] For example, the wavelength multiplexing machine 2 which connected and formed in two steps an optical multiplexing means to have multiplexed and to transmit the light from which the wavelength by which incidence is carried out from an incidence side [2] transmission line, respectively differs to one outgoing radiation photometry transmission line is typically shown in drawing 11 , and the optical multiplexing function by the above-mentioned optical multiplexing means is hereafter explained to it briefly using this drawing.

[0090] In addition, in this drawing, the sign 401,402,403 is given to each optical multiplexing means, and the multiplexing light center wavelength it multiplexes [wavelength] by these optical multiplexing meanses 401,402,403 has the peculiar period, respectively. Moreover, the peculiar period of the optical multiplexing means (being $n=2$ here the 1st step of optical multiplexing means 401,402) prepared in eye the stage (n-1) is accomplished with the integral multiple of the peculiar period of the optical multiplexing means 403 prepared in the 2nd step.

[0091] Here, when it asks for the insertion loss of the light which inputs from a port 305 and is outputted from a port 307 about the optical multiplexing means 403, it is shown in the ultimate lines a of (a) of drawing 12 , and the ultimate lines a of (b) of this drawing. That is, in this case, in the optical multiplexing means 403, it is inputted from a cross port, and the multiplexing light center wavelength (main wavelength of the light it can multiplex [light] with low loss) it is multiplexed [wavelength] becomes λ_A , λ_B , λ_C , λ_D , and ... in addition -- although it is inputted from the through port (port 306) of the optical multiplexing means 403 and the multiplexing light center wavelength it is multiplexed [wavelength] is not illustrated in this drawing -- the wavelength between λ_A and λ_B , and the wavelength between λ_C and λ_D -- since it becomes ... (refer to (a) of drawing 6), the peculiar period of the optical multiplexing means 403 turns into a period of the half of $\Delta\lambda$

[0092] Moreover, if it asks for the insertion loss of the light which inputs from a port 301 and is outputted from a port 305 about the optical multiplexing means 401, it will become what is shown in the ultimate lines b of (a) of drawing 12 , and the multiplexing light center wavelength it multiplexes [wavelength] by the optical multiplexing means 401 in this case will become λ_A , λ_C , and ... If it asks for the insertion loss of the light which

inputs from a port 302 and is outputted from a port 305 about the optical multiplexing means 401 on the other hand, it will become what is shown in the ultimate lines b of (b) of this drawing, and the multiplexing light center wavelength it multiplexes [wavelength] by the optical multiplexing means 401 will become λ_B , λ_D , and ... That is, the peculiar period of the optical multiplexing means 401 is ΔS , and serves as double precision of the peculiar period of the optical multiplexing means 403.

[0093] Thus, by setting up the period of the optical multiplexing means 401 and the optical multiplexing means 403, and connecting the optical multiplexing means 403 to the latter part of the optical multiplexing means 401 In both ultimate lines a and the ultimate lines b, as it will be outputted from a port 307 and shown in the ultimate lines c of (a) of this drawing, only the wavelength of a low insertion loss Among the light inputted from a port 301, the light of wavelength λ_A , λ_C , and ... is outputted with low loss from a port 307, and the light of wavelength λ_B , λ_D , and ... is outputted with low loss from a port 307 among the light inputted from a port 302.

[0094] In this invention therefore, the wavelength multiplexing machine 2 Two or more steps connect and an optical multiplexing means to multiplex and to transmit the light from which the wavelength by which incidence is carried out from an incidence side [2] transmission line, respectively differs to one outgoing radiation photometry transmission line is constituted. By accomplishing with the integral multiple of the peculiar period of an optical multiplexing means in which the peculiar period of an optical multiplexing means by which the multiplexing light center wavelength it multiplexes [wavelength] by each optical multiplexing means shall have a respectively peculiar period, and was prepared in eye the stage (n-1) was prepared in the n-th step The same effect as each above-mentioned example of an operation form can be done so.

[0095] However, since these production technology, functions, etc. are common knowledge when the Mach TSUENDA interference-pattern multiplexing means 6 and the melting type fiber coupler 4 constitute the above-mentioned optical multiplexing means, it is easy performing production of the wavelength multiplexing machine 2 etc., and the excitation light source equipment which does so the effect which was excellent the account of a top can form certainly like each above-mentioned example of an operation form.

[0096]

[Effect of the Invention] Since according to the 1st invention the polarization light from which a polarization state and wavelength differ mutually is multiplexed with a polarization composition vessel and the multiplexing light is inputted into a wavelength multiplexing machine from the one or more optical input sections of a wavelength multiplexing machine The number of the optical input section prepared in a wavelength multiplexing machine can be lessened only several arrangement minutes of a polarization composition machine, the insertion loss of a wavelength multiplexing machine can be reduced, it multiplexes and the excitation light of much wavelength can be outputted by high power.

[0097] In the 2nd invention which connected two or more steps and formed especially an optical multiplexing means for a wavelength multiplexing machine to have multiplexed the light from which the wavelength by which incidence is carried out from an incidence side [2] transmission line, respectively differs, and to transmit to one outgoing radiation photometry transmission line, in this invention Since the number of the optical input section of a wavelength multiplexing machine can be lessened only several arrangement minutes of a polarization composition machine like the above the number and the number of stages of an optical multiplexing means which form a wavelength multiplexing machine can be reduced, and in a wavelength multiplexing machine with many number of stageses, the problem of the formation of wavelength-range region narrow width of face of the multiplexing light which was a problem can be suppressed, and the insertion loss of a wavelength multiplexing

machine can be boiled markedly, and can be reduced

[0098] Therefore, according to the 1st and the 2nd invention, it becomes possible to offer the excitation light source equipment which multiplexes and can output the excitation light of much wavelength by high power, and, thereby, improvement in the Raman amplification efficiency of a Raman amplification type light amplifier can be aimed at.

[0099] Furthermore, according to the 3rd invention, the multiplexing light center wavelength it multiplexes [wavelength] by each optical multiplexing means has the peculiar period, respectively. (n-1) Since the peculiar period of the optical multiplexing means prepared in eye the stage (n is two or more integers) is accomplished with the integral multiple of the peculiar period of the optical multiplexing means prepared in the n-th step By the optical multiplexing means connected two or more steps, the excitation light from the excitation light source can be multiplexed with low loss, and the excitation light source equipment which does so the effect which was excellent the account of a top can be formed certainly.

[0100] Furthermore, by making an optical multiplexing means into the Mach TSUENDA interference pattern multiplexing means equipped with two directional couplers, respectively like the 4th - the 7th invention, or considering as a melting type fiber coupler, a wavelength multiplexing machine can be produced easily and the excitation light source equipment which does the above-mentioned effect so can be offered certainly. [Claim(s)]

[Claim 1] The excitation light source equipment characterized by to have the wavelength multiplexing machine which multiplexes the light of two or more mutually different wavelength, and for the optical output section of the polarization composition machine which multiplexes two polarization light from which a polarization state differs mutually in the one or more optical input sections of this wavelength multiplexing machine to be connected, and to be connected the two excitation light sources which output the polarization light from which a polarization state and wavelength differ mutually to the optical input section of this polarization composition machine, respectively.

[Claim 2] A wavelength multiplexing machine has two or more optical multiplexing meanses of the 1st step to multiplex and to transmit the light from which the wavelength by which incidence is carried out from an incidence side [2] transmission line, respectively differs to one outgoing radiation photometry transmission line. So that the optical multiplexing means of the 2nd step which carries out optical multiplexing of the optical output of the optical multiplexing means per pair of these 1st step further may be connected and the optical output of a pair of optical multiplexing means of the preceding paragraph may be referred to as carrying out optical multiplexing further with a latter optical multiplexing means Excitation light source equipment according to claim 1 characterized by connecting an optical multiplexing means to two or more steps, and being formed.

[Claim 3] The peculiar period of the optical multiplexing means which the multiplexing light center wavelength it multiplexes [wavelength] by each optical multiplexing means has the peculiar period, respectively, and was prepared in eye the stage (n-1) (n is two or more integers) is excitation light source equipment according to claim 2 characterized by having accomplished with the integral multiple of the peculiar period of the optical multiplexing means prepared in the n-th step.

[Claim 4] An optical multiplexing means is excitation light source equipment according to claim 2 or 3 characterized by considering as the Mach TSUENDA interference pattern multiplexing means equipped with two directional couplers, respectively.

[Claim 5] A directional coupler is excitation light source equipment according to claim 4 characterized by considering as a melting type fiber coupler.

[Claim 6] A Mach TSUENDA interference pattern multiplexing means is excitation light source equipment according to claim 4 characterized by forming by the optical waveguide circuit.

[Claim 7] An optical multiplexing means is excitation light source equipment according to claim 2 or 3 characterized by considering as a melting type fiber coupler.

[Translation done.]